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The Fingertip Effect: How Information-Processing Technology Shapes Thinking

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ABSTRACT: Contemporary beliefs about the impact of information-processing technology (IPT) on thinking are examined. Whereas some suggest that learning to program and other contacts with IPT will empower thinking, it is argued from both theory and evidence that typical contacts with IPT today do not meet certain conditions for significantly reshaping thought. Whereas others suggest that IPT will have a narrowing and dehumanizing influence, it is argued that the striking diversification of IPT now underway will eventually allow for many styles of involvement. In the long term, as this diversification spreads to nearly all aspects of society, thinking may change in certain basic ways as it has in response to literacy and print.

"What difference will it make?" is at least two questions in one. If the "it" is a technology such as the automobile, the telephone, or computers, the straightforward difference concerns what you can do that you could not before—commute significant distances to work, converse with friends, relatives, and business associates from afar, and carry out computations or construct interactive systems. Technology has a venerable history of putting things at our fingertips to be seized and used widely for their designed objectives as well as for other purposes.

We can call this the first order fingertip effect, the difference an innovation straightforwardly makes. But a further question is often asked: "What difference will it *really* make?" The "really" refers not to the pragmatics of commuting, communicating, or computing, but to deeper and more wide-ranging repercussions on society, personality, and thought. The question recognizes that a technological innovation might change the way people do certain things without actually changing very much the basic aspirations, endeavors, or thinking habits of a population.

For a long time, technology dealing with symbolic media has invited thoughtful questions and speculations about second order fingertip effects. History testifies to the worth of such questions. The technology of print plainly has changed the nature of society and thought in radical and far-reaching ways. Having information on all sorts of subject matters at our fingertips not only informs us about practical activities like baking a cake from a recipe, but also broadens horizons and fosters combinatorial work and play with the data and ideas supplied by print. Moreover, Olson (1976) and others have argued that high-level thinking is not just fueled by the printed word but employs writing as a vehicle in which to think. As philosophers, physicists, city planners, or advertising people, we think more complexly with the surrogate memory of a sheaf of notes than we possibly could in our heads. The limits of short-term memory and the schematic character of oral tales (Lord, 1974) testify to how much writing enables complex combinatorial thinking.

The spread of television provokes another round of "What difference does it *really* make?" questions, usually rather nervous ones. But already a tide of technology has swept us along to newer hopes and worries. The advent of information-processing technologies such as hand calculators, video games, home computers, and interactive videodiscs has revived the issue of fingertip effects more than any innovation since print. As numerous thinkers have emphasized, for the first time symbolic media like words and images can figure

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in highly interactive systems, which if well designed can respond fluently to the user's needs and progess. Whereas a book just sits waiting to be used, a computer tutorial can guide the student. Whereas data on the stock market ticker tape await inspection, computers can scan a data base and ring a "sell" alarm or highlight opportunities.

Flexibility is as important as the active and interactive character of information—processing technologies. Revision is readier on a word processor; computations are handier on a hand calculator. By reducing onerous mechanics, the new symbolic technologies may free us to attend in new ways and aspire to new levels of cognition. One might put it this way: The written word extended the reach of thought by helping us to circumvent low-level limitations of human short-term memory. Information-processing technologies might further extend the reach of thought by helping us to circumvent low-level limitations of human computational ability, including not only computation with numbers but with words and images.

At the same time, some forecast darker effects. We may lose our humanism and become overtechnologized. Symbol processing may simply amplify the logical linear character so often attributed to print, taking us further down what some see as a primrose path. Video games may seduce our youth into frivolous fantasy. On analogy with what we fear from television and fast food chains, these innovations may prove great levelers, making society more uniform if not more mediocre. All such concerns represent the dark side of the fingertip effect: With certain things at your fingertips, you may neglect other equally important but not so handy matters with a serious net loss.

No one doubts the first order effects—that the new technologies will prove enabling in certain directions, or that society will by and large embrace their power. Many people wonder what deeper repercussions there may be, hope or fear them, and ponder how to promote or parry them. But wonder, hope, and fear are not our only recourses. We can also think critically about the effects of information-processing technologies thus far observed and about the soundness of analogies with other innovations such as television or print. Perhaps by being clever and careful we can forecast what fingertip effects are really likely. With no more guarantee than the weatherman ever gives, let us see what can be done.

The "Opportunities Get Taken" Hypothesis

Many people have pointed out that information-processing technology puts at our fingertips opportunities for better thinking and learning. Perhaps the best known herald of this hope is Seymour Papert, one of the inventors of the Logo computing language. Logo, related to LISP but designed for accessibility, lets youngsters do programming projects that promise significant payoffs. How might such benefits accrue? One example is "turtle graphics," a mainstay among Logo programming activities. While programming fields of flowers or abstract designs, students may pick up certain notions about angle and distance, shape and line with relevance to mathematical understanding. Logo programming activities can be directed more specifically at understanding mathematical concepts (Feurzeig, Papert, Bloom, Grant, & Solomon, 1969; Feurzeig et al., 1971). Beyond questions of content, engagement in programming might impart concepts of scope and power, such as the notion of a "bug." Carrying a procedural perspective from Logo programming activities to other tasks like writing an essay or learning to pole vault, the learner might analyze the procedural demands, devise a program-like plan, and debug it on the basis of experience. In general, programming offers a host of concepts inviting analogy and application to other procedural contexts.

If Logo puts certain notions at learners' fingertips, similar opportunities exist in other information-processing technologies. The word processor is a case in point. It has been suggested that word processors can liberate the young writer from the labors of retyping or rewriting in pencil and from the bewilderment that a forest of hand-corrections on a document brings. Typically student writers need to edit more, not only in small ways but in structural ways such as adding substantial text in the middle or moving around chunks of text. The inconvenience of such actions discourages them; word processing frees the student to do the right thing.

A similar story of promise can be told for other symbol-handling technologies. Data bases, for example, have become favorite resources for teachers seeking to marry computers to history, civics, or biology. Like Logo supposedly does, data bases carry a message in the medium: Classification and cross-classification is a powerful intellectual tool. Moreover, having an array of information at your fingertips potentially lets you inquire about a topic far more flexibly than you can in libraries.

All these cases share what might be called the "opportunities get taken" hypothesis. In Logo this means that students using the language will learn the deeper lessons the language affords. In word processing it means that students will recognize and exercise the option of easy large-scale editing. In data bases it means that students will formulate interesting questions and harvest answers to them from the data base, acquiring along the way a feel for categories and classification.

Although the final returns will not be in for years, results at hand cast doubt on this hypothesis. Most typically, it seems, the opportunities are not taken. Researchers at Bank Street College of Education (Pea & Kurland, 1984; Kurland, Clement, Mawby, & Pea, in press) have conducted studies seeking transfer effects from Logo programming to a planning task unrelated to programming and to a planning task with a programming character. They also have examined students' progress in acquiring concepts and practices within Logo that might later transfer to other contexts. In a nutshell, these investigations have disclosed no transfer of skill and poor learning within Logo itself.

An equally cautionary tale applies to word processors. Daiute and Kruidenier (1984) and Daiute and Kruidenier (in press) conducted an extensive study of the impact of one year of word processing-based writing instruction on seventh through ninth graders, with some students simply using the word processor for writing and others using it with a prompting program designed to provoke intelligent revising by asking questions like "Does this paragraph make a clear point?" The authors summarize some of their results as follows:

> This study showed that when factors such as composing time, topic, and composing procedures are held constant, sustained change in revising strategy depends on instruction (i.e. by the prompting program) more than on a writing instrument like the word processing program that could facilitate revising. It also takes more than a school year, even with typing instruction, for junior high school students to become as fluent with the

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> computer as they are with pen. The evidence for this conclusion is that students' texts on the computer include fewer words than those in pen, and these texts on the computer receive lower holistic quality ratings. (p. 38)

I cannot cite any data for applications of data bases, but I do have an impression from some conversations: For what such "data" are worth, it seems that students have trouble coming up with really interesting questions to ask of the data base.

Note that with the exception of the prompting program of Daiute and Kruidenier (1984), none of the situations considered here included a direct effort to *teach* general strategies or mental models for programming, editing, or question-formulating. Evidence exists that such general strategies can be taught and do prove useful (Belmont, Butterfield, & Ferretti, 1982; Palinscar & Brown, 1984; Schoenfeld, 1982; Schoenfeld & Hermann, 1982). Indeed, the Daiute and Kruidenier study suggests this for word processing with the prompting program. But the "opportunities get taken" hypothesis purveys a different philosophy: The opportunity does the teaching by itself. Often it is even urged that direct teaching may do mischief by forcing the issue in an unmotivated and acontextual manner. Certainly the vision of learning a general lesson naturally by taking an opportunity has enormous attraction. But it does not seem to happen with the reliability one would like.

Why Do Opportunities Not Get Taken?

How would they get taken? If we suppose a relatively mindful process of opportunity taking, there are perhaps three conditions: (a) the opportunity is really there, (b) learners recognize it, and (c) learners are sufficiently motivated to take it. Perhaps we can understand how things go wrong in terms of one or more of these conditions failing.

Is the opportunity really there? In my view, the answer here is largely affirmative. Programming in Logo and other languages does offer potential lessons in metacognitive and other matters; texts frequently would benefit from radical editing, which word processors make possible, and so on. The opportunity has been argued well by Papert (1980), Feurzeig et al. (1969, 1970), and others. There have been encouraging case studies about some students' response to Logo (Watt, 1979). Clements and Gullo (1984) reported positive transfer from Logo instruction to measures of ideational fluency and cognitive style. Clinical research on novice programmers in primary and secondary school settings has disclosed patterns of problem-solving conduct, some of which could apply to other disciplines as well. For instance, while some students disengage from a programming problem as soon as they encounter difficulties, others keep moving as best they can; while some students make no attempt to break down a problem into subproblems, others do (Perkins, Hancock, Hobbs, Martin & Simmons, in press). Perhaps in the right circumstances those students who do not begin programming with good problem-solving practices could learn them in the programming context and even transfer them to other contexts.

Do learners recognize the opportunity? Here it is easy to doubt. What is it about a programming experience in Logo or a writing experience with a word processor that should alert a student to the opportunities, in the absence of explicit instruction about them? The writing student, for example, lacking convenient opportunities for radical revision before, will not have developed a disposition to do such editing and will not have any sense of what it would entail. To be sure, given enough time and enough learners, such opportunities will get discovered, but how quickly? One study from a different domain speaks to this question.

In his work on teaching heuristics for mathematical problem solving, Schoenfeld (1979) conducted a small-scale but telling experiment contrasting students' learning of heuristics and improvement in problem-solving abilities under two conditions. Under one condition, the examples worked out for the students used certain heuristics without identifying them explicitly. The other condition was identical except that overlays identified the heuristics. Schoenfeld found that the explicit heuristics group improved in problem-solving abilities and did so by using the heuristics. The other group did not improve at all and also did not abstract any heuristics from the models seen. This seems to be a clear case of failing to recognize what was explicitly modeled but not explicitly identified. It suggests that, at least in the short term, opportunities are not taken because they are not perceived.

Are learners sufficiently motivated to take the opportunity? Here again there is room for doubt. A new opportunity, even if perceived, often requires considerable effort for unclear gain. In writing stories, for example, why should a student aware of the theoretical possibility of radical revision make the effort, even though word processing facilitates it, when the student probably does not have a sharp sense of how much such editing can enhance a story? Likewise, we cannot expect students writing essays to appreciate the value of a well elaborated argument even though they might know they could edit in any elaborations they wanted to. In empirical work on students' construction of arguments, Perkins, Allen, and Hafner (1983) point out that most people function as "makes sense epistemologists." Once they reach a line of argument that makes superficial sense, they see no need to develop additional supporting lines of argument or to consider the other side of the case. It is as though avoidance of cognitive load rather than epistemic needs dominates their behavior.

Regarding programming, Kurland et al. (in press) report that whereas some students after a certain amount of Logo experience cannot display structured programming practices even on demand, other students can but avoid them. The problems posed to the students do not absolutely demand such practices, and the students opt for the simpler tactic of piecemeal "spaghetti programming," as it is called. Again, it seems that avoidance of cognitive load in the absence of any real press to behave more elaborately leads to failure to exercise higher-level skills.

The argument so far assumes a relatively mindful process of discovering and taking opportunities. Another view might be that learners gradually "soak up" the implicit general opportunities afforded by programming, word processors, and other information technologies. Perhaps written language provides the best analogy here. Literacy, as studied by Luria (1976), appears to lead to fundamental changes in cognitive function, as measured by performance on categorizing tasks, syllogisms, other sorts of formal tasks, and problems with a practical slant as well. There is no need to posit any mindful process of calculated abstraction. The high level knowledge accumulates covertly, being latent in the very fabric of the activity.

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The medium is the message.

In writing on transfer of learning, Salomon and Perkins (1984) and Perkins and Salomon (in press) have elaborated just such a distinction. They contrast two kinds of mechanisms for learning and transfer of learning, the "high road" and the "low road." High-road transfer occurs by mindful abstraction of principles and application of them to new contexts. For instance, while playing "twenty questions," one might recognize a general "divide in half" strategy and become alert to opportunities to apply it elsewhere. Low-road transfer occurs through varied practice and automatization; a skill exercised in one context, then in another somewhat different context and in another still more different context gradually gets "stretched" to suit a range of applications without any mindful abstracting of principles. For instance, perceptual-motor skills acquired through practicing scales and other exercises generalize to passages of like character in the midst of compositions; moreover, such passages, differing as they do from the idealized exercises, "stretch" the skill, which becomes less and less bound to the details of the original exerices.

With this distinction in mind, the low road as well as the high road could lead to taking the opportunities in question. Why does this not happen? Salomon and Perkins (1984) argue that low-road transfer calls for *extensive, varied* practice. By this formula, only years of programming experience on a variety of programming tasks should yield higher level skills suitable for a range of programming tasks. Consistently with this, Mawby (in press) reports a crucial observation about very skilled young programmers: Without exception, several interviewed disclosed enormous time on task. No instances of overnight wonders have surfaced. The same point has been made for other areas of performance as well, such as chess play (Simon & Chase, 1973) and composing music (Hayes, 1981). For low-road transfer beyond the context of programming, learners would need a series of experiences somewhat like programming to stretch their skills to other domains. Certain situations calling for planning and certain kinds of mathematical problem-solving might offer such bridge experiences, but again low-road transfer requires considerable time.

In further evidence, the same limitation seems to apply to literacy as well. Scribner and Cole (1981) report a study of the Vai, an African tribe that evolved its own written language. Some Vai master the Vai script, some Arabic, some both, and many neither. In contrast with Luria's (1976) findings, the literate Vai exhibit hardly any of the cognitive characteristics usually expected of literate people. Scribner and Cole explain this by contrasting literacy with schooling, which Luria's findings reflect. Whereas schooling not only involves much more than literacy but feeds a number of professions and roles within a society, literacy per se can be far narrower in scope. Indeed, within the Vai culture the literacy has very narrow applications; a literate Vai will live pretty much the same life as an illiterate Vai, except for certain restricted activities like letter writing or reading the Koran. In other words, literacy in the Vai culture fails the second condition for low-road transfer: *varied* practice.

In understanding why the second order opportunities afforded by information-processing technology often do not get taken, we arrive at something positive: some sense of how to get them taken. One can foster the high road, offering the opportunities with explicit instruction and press. One can, for instance, teach high-level Logo programming skills more directly and pose problems that virtually demand their exercise. One might even go on to underscore connections between these high-level principles and nonprogramming situations. Recently Clements and Gullo (1984) reported significant gains on measures of ideational fluency and cognitive style from 12 weeks of Logo, two 40-minute sessions per week, with a small group of students who, according to the description of the treatment, received extensive high-level guidance from teaching assistants. Likewise, instruction in the use of word processors could go hand in hand with an explicit exploration of how to take advantage of the editorial freedom they offer. Instruction organized around data bases could include direct attention to what makes a good question for the data base and how to think up such questions.

Low-road learning offers another route. Most people would doubt that many course-years of school time should be committed to programming. But writing, for instance, might be another matter. Writing is so central a performance that a writing program based on word processors might well continue year after year, with a gradual broadening of students' range and power via the low road. Of course, low-road learning may not give us all we would like from an innovation; although print and writing afford some very sophisticated thinking and have been around for a long time, relatively few people take the opportunity fully. But the two roads, metaphors as they are, can be travelled at once. The ideal instructional program would involve direct attention to principles to foster high-road learning and transfer and extensive varied practice to foster low-road learning and transfer.

The first order fingertip effect occurs spontaneously. Given word processors, people take advantage of their most immediate conveniences. Given programming languages and minimal instruction, students tinker with them and often do some interesting things. But the second order fingertip effect does not just happen by itself. It occurs only under certain conditions—the conditions for low-road or high-road learning and transfer. A few individual learners may, because of their talents, enthusiasms, and life circumstances, find one or the other road by themselves. But to harvest the benefits on a wide scale, one must engineer those conditions, as schooling does to a considerable extent for literacy.

The Technology Trap

As mentioned at the outset, negative fingertip effects are feared as much as positive ones are hoped for. The misgivings find their inspiration in analogies and exemplars of what might go wrong. Looking to the preoccupation of many youngsters with video games, some see a mesmerism more potent than television. Because video game parlors become hangouts of a sort, some fear new forms of delinquency as gamesters push drugs or commit petty thefts to feed their video habits. Computer hackers, too, are perceived as victims of an alarming Pied Piper effect.

Such kinds of enthrallment aside, an overly technological cant to thoughts and behavior might dehumanize society. The image of computers as inflexible mechanisms demanding a dogged precision in their care and feeding forecasts a society bent in that direction. Shakespeare, Christmas, and family picnics seem regrettably old hat. Simple mediocrity poses another threat. As television and fast-food chains level standards and homogenize regional character,

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snowballing technology and the flood of information channelled via such technology might accelerate this social entropy. These worries make us recognize a flip side to the fingertip effect. As certain things become accessible, others get ignored. The attractiveness and convenience of information-processing technologies may prove an unfortunate seduction.

With such hazards in mind, what can be said about events so far? Looked at with care, recent history does not seem to support the worst forebodings. Video games provide a case in point. No more than a year or two ago, video games were a serious public issue, a focus of national conferences and even legislative action. Today, it has all blown over. Besides the video game industry itself cresting and declining, concerned researchers investigating video games and their social settings began to map a reality that previously had been constructed mostly of anecdotes and anxieties.

The reputation of video game parlors as centers of rebellion proved unwarranted. Alarming episodes of youngsters trafficking in crime to feed their video game habits rarely emerged. From a vision of loners absorbed in a Quixotic quest to defend the galaxy, the picture changed to one of a peculiarly social event, youngsters spending abundant time watching and talking, not just playing (Brooks, 1983a, 1983b). Home use of video games also offered some social benefits rather than fostering distance and isolation (Mitchell, 1983). Moreover, promise of cognitive benefits from video games began to emerge in certain quarters. Drill and practice programs dressed up as video games might motivate slow learners to master skills of spelling and arithmetic (Chaffin, 1983). Brain damaged individuals might benefit from the cognitive exercise video games can provide (Lynch, 1983). A whole array of opportunities for educational applications of video games formats became apparent, albeit with some roadblocks in the way of their best use (Perkins, 1983). It is not that video games on inspection emerged as the boon of the '80's. A closer look revealed a rather normal picture of youths engaged in an enthusiasm along with several prospects for valuable special-purpose applications.

In *The Second Self,* Sherry Turkle (1984) also provides a helpful perspective on the impact of information-processing technology. Perhaps more than any single generalization Turkle makes, one is impressed by the sheer diversity of reaction. While some become hackers, some shun contact with the new machines. While some take what Turkle calls a "hard" approach to programming, others adopt a "soft" style. The computer serves as a surrogate companion, a metaphor for mind, a symbol of involvement in modern society. It seems most of all a locus of projection, a remarkably plastic symbol that people assimilate to their predilections, rather than a rigid presence to which people accommodate.

Mediocrity and mechanization certainly make themselves felt in software, toys, and other devices. But an upward trend is manifest. Drill and practice, the bane of educators oriented toward more mindful activities, at least is acquiring a prettier package through video game formats and engaging graphics. Software that affords opportunity for exercising whimsical invention, such as the well known *Rocky's Boots*, appears more and more. Mice, Mac Paint, and touch screens soften the hard-edged image of the computer. "User friendly" gradually is becoming less of a promise and more of a reasonable expectation. In the face of foreboding, we should wonder why things seem to be going so well.

Why the Technology Trap Does Not Trap

Such cultural icons as ABC, McDonald's, and IBM, along with the Whorfian hypothesis that any symbol system channels us in subtle ways, all forecast problems of narrowing and leveling. To see why things might go better, we need to understand how those weather signs can mislead. Broadly speaking, diversity in a medium depends on its potential for diversity and the mechanics of realizing that potential. For example, sky writing has low potential for diversity, given the brevity of messages and the swift work of the wind. As to mechanics, sky writing has a very high cost per word that tends to limit it further. How do these considerations of potential diversity and mechanics apply to symbol handling technologies?

Regarding potential, the image of the computer as a rigid calculating instrument foretells a narrow range of applications. To be sure, this connotation comes naturally with an instrument composed of logic gates. But the connotation is deeply misleading. Computers and their associated input/output devices comprise the most flexible symbolic medium ever devised. It is, of course, the software that makes the difference. Software can be as diverse as the ingenuity of the designers and programmers—drill and practice, Socratic tutoring, electronic books, simulation games, word processors, data bases, economic models, models of the weather, computer art, and who knows what next. In terms of their capacity to represent different kinds of information, computer systems have no peer. Not only print but images, static or moving, become possible through computer animation and the use of videodisc. Sound technology affords music, speech, and even, to some extent, speech recognition.

At present, some of this flexibility exists more in principle than in practice. Speech recognition is not yet very good; interactive videodisc systems are few. But the technology is very young, so we need not expect everything at once. Surely if there is a hidden narrowness in the multidimensional symbolic medium of information-processing technology, it is nothing so unsubtle as being inexorably verbal, categorical, or logical.

If at present the applications of information-processing technology seem to cut a narrow path, it is well to remember the history of the book. Initially, books addressed only a few urgent topics. Now, after centuries of diversification, there are books on every topic for any reader—novels for children, teenagers, grownups, magazines for boy scouts, mercenaries, dungeon and dragon enthusiasts, pornography for the crude and sophisticated, the straight and kinky. One is reminded of biological evolution where life forms diversify in the course of time to fill a bewildering array of biological niches. It seems there are intellectual and economic niches for books in society just as there are lifestyle niches in the biosphere. Books have gradually been filling those niches.

The analogy with information-processing technologies should be plain. Very likely society includes a multitude of potential economic and intellectual niches for information-processing technologies. We have only begun to find out what they are and how to fill them. In 50 years, information-processing technologies may be as endlessly diverse, omnipresent, and taken for

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granted as print. Perhaps more so, given the inherent ability of information-processing technologies to function more flexibly with print, images, and speech.

Having dwelled on the potential for such expansion and diversification, we would do well to consider the mechanics also. Television has its cautionary tale to offer. Decades ago the potentials of television for remaking education and informing a society seemed bright, but the intervening years have taught a lesson about the economics of mediocrity. Despite the seeming flexibility of information-processing technologies, might not they go the way of television?

This analogy fails to recognize the forces that make television what it is. These forces have little to do with the nature of the symbolic medium and much to do with its mechanics. Mainstream television suffers from the key problem of limited channel capacity; there are only three private networks, one public network, and a few thousand local stations in the United States. This is a veritable recipe for mediocrity, especially in light of the enormous cost of television production and the consequent need for any one program to reach a large public. A more sophisticated audience cannot easily be served because air time is a scarce resource; giving the more sophisticated audience something means depriving the larger, less sophisticated audience, not just expanding services. A bias toward the lowest common denominator becomes inevitable.

One sees no such narrowness in the publishing of books, because different markets can be served in parallel. By the same argument, cable TV and video cassettes should alleviate the limited channel problem and allow a broadening of television fare. Such a trend is plainly visible already in cable television's specialized sports, arts, and religion networks. Clearly the limited channel problem does not apply to information-processing technologies in general. The ready implication is that we should not expect a dogged mediocrity. There will be plenty of mediocrity of course, just as there are multitudes of mediocre books. But there will also be plenty of enlightened applications.

All in all, a close inspection of the images that predict disaster—computers as logic boxes, mindless television, and so on—discloses misleading connotations and analogies. Enormously flexible, potentially applicable to artistic and humanistic endeavors as well as scientific and business enterprise, and readily adaptable to moderate-sized markets, information-processing technology represents a force for diversification, not homogenization—a technology for all seasons.

Dilemmas of Diversity

Earlier I concluded that the opportunities for more mindful productivity implicit in programming languages, word processors, and so on rarely got taken. Now I urge that the feared technologizing and homogenizing influence of information-processing technologies mismatches the reality of a diverse medium that will come to fill a multitude of roles as society discovers the opportunities. Is this consistent?

It surely is, and the explanation turns on the circumstances for low-road and high-road learning and transfer and matters of time scale. Opportunities for mindful productivity were not likely to be taken in the short term because the conditions for low-road or high-road learning and transfer were not met. But the gradual diffusion of a technology throughout the culture sets the stage for low-road learning and transfer, which depends on extensive varied practice. By encountering certain ways of handling information in many contexts over a long period of time, people gradually should achieve at least some of those second order opportunities. As already mentioned, print has had such an effect, in a real sense making people modestly more intelligent. Likewise, on a scale of time suitable for low-road learning and transfer, information-processing technology will make people modestly more intelligent. If we want to speed up the process and carry it further, we can teach principles directly, adding high-road learning and transfer to low road.

All this has its price, however. Although I have argued that information-processing technology feeds diversity rather than homogeneity, the diversity tends toward self-consciousness rather

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than innocence. Biological diversity, and, until recently, social diversity, are innocent. As Darwin proposed, the creatures on one island differ from the creatures on another for lack of communication—in that case, genetic communication. Likewise, cultures have owed their differences to social, rather than genetic, isolation or partial isolation, brought about by geography, language, and other factors. Diversity in its natural form follows from a low order of information exchange.

Information-processing technology and modern media in general work against innocent diversity. Innocence aside, diversity survives and even thrives. Many people succeed in holding onto their ethnic origins. The new technologies themselves create a myriad of opportunities that different people take in different ways, in effect creating new and varied niches within society. Moreover, the innocent diversity of isolation leads to a dismaying blindness, a dangerous Tower of Babel effect.

But innocent diversity has its pleasures. Increasingly, those who opt for a particular faith cannot help but know that there are a hundred other faiths with people just as sincerely committed to them. Those who embrace their ethnic origins know that a hundred other cultures have proud heritages as well. Those who adventurously enter a particular niche just evolving in society cannot easily ignore the existence of a hundred other options. You cannot even be a fanatic nowadays without knowing it. One can get lonely among the choices, disconcerted by the arbitrariness and insignificance of any one election among the many.

In short, if we have something to fear from the impact of information-processing technology, perhaps it is not so much the malaise of homogeneity as the malaise of self-conscious diversity. Such diversity is not the most comfortable or confident kind. It should, however, tend to bring more mindfulness and empathy, less crisis and conflict. Ambivalence is a price intelligence often exacts, but at least we gain something in return.

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